Coronal Heating

Ronald L. Moore/ES82
205–544–7613
E-mail: ron.moore@msfc.nasa.gov

The Sun's extended outer atmosphere, the corona, is so hot that it radiates predominantly in soft x rays (1 to 10 nm in wavelength). The upper left panel of figure 169 shows a typical whole-Sun soft x-ray image taken by the Japan/U.S. Soft X-Ray Telescope (SXT) on the Japanese orbiting spacecraft, Yohkoh. This image demonstrates that in soft x rays the corona greatly outshines the underlying photosphere, the Sun's surface seen in ordinary visible sunlight. This requires that the x-ray coronal plasma be maintained at million-degree temperatures, hundreds of times hotter than the photosphere. How the necessary coronal heating is accomplished remains an unsolved puzzle, constituting a long-standing premier problem of solar physics and astrophysics.

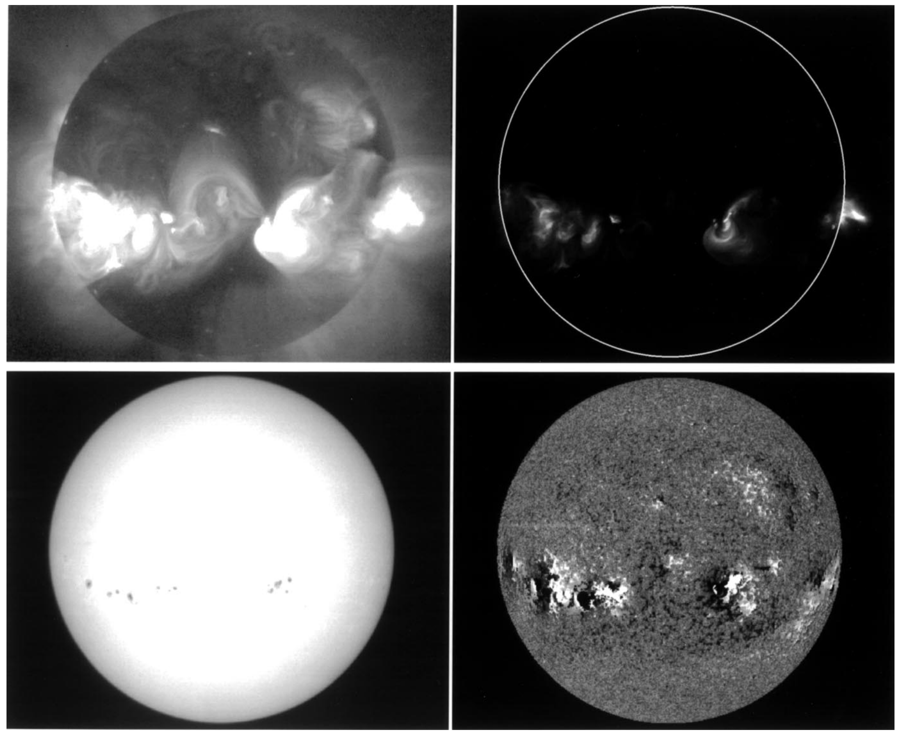

FIGURE 169.—The x-ray solar corona and its magnetic roots.

Figure 169 illustrates that coronal heating is a magnetic phenomenon: the strongest heating (brightest corona) is seen to be in the strong magnetic field in sunspot regions. (The upper right panel of figure 169 is the same SXT coronal image as in the upper left panel, but with a different scaling of the brightness to show detail within the brightest regions. The lower left panel is a cotemporal photospheric image showing sunspots underlying the most strongly heated parts of the corona. The lower right panel is a conventional magnetogram from Kitt Peak National Solar Observatory showing both the concentrations of strong magnetic field in the bright-corona active regions (in and near sunspots) and scattered weaker fields in dimmer-corona quiet regions (well away from sunspots.) It can be seen from even a cursory comparison of SXT coronal images with conventional magnetograms (maps of the line-of-sight component of the photospheric roots of the magnetic field), such as in figure 169, that the brightest coronal features in an active region occupy only some parts of the strong-field domain of the active region. While it is true that the brightest coronal features are seated in strong fields, there are other places in the active region where the field is as strong or stronger, but the corona is much dimmer, and hence the heating much weaker. Thus, it is clear that the strength of the enhanced coronal heating in active regions depends on more than just the strength of the magnetic field.

During the past year, solar scientists at MSFC, in collaboration with U.S. and Japanese colleagues participating in the Yohkoh Mission, have established some new characteristics of the magnetic origins of the strong coronal heating in active regions. They examined the structure of the magnetic field at the sites of strong coronal heating in five active regions by superposing Yohkoh SXT images on vector magnetograms of these active regions from the MSFC vector magnetograph. (A vector magnetograph maps the transverse component of the photospheric magnetic field in addition to the line-of-sight component mapped by conventional magnetographs.) They found:

- Nearly all of the enhanced (outstandingly bright) coronal features are rooted near polarity neutral lines in the photospheric magnetic flux;
- In most cases the core magnetic field closely straddling the neutral line at the root of the strong heating is strongly sheared;
- The enhanced coronal brightness in the low-lying core fields shows spatial substructure that fluctuates on time scales of minutes, in the manner of microflaring;
- Large parts of extensive enhanced coronal features often last for no more that a few hours; and
- Some strongly sheared core fields and many weakly sheared core fields have no enhanced coronal loops in them or extending from them.

From these results, they conclude that most of the strong heating of coronal loops in active regions is a consequence of some process that:
- Acts only in the presence of a polarity inversion in the magnetic field near at least 1 ft of the loop, and is more effective in the presence of strong magnetic shear, but
- Is not required to act by the presence of a neutral line or strong neutral-line magnetic shear;
- Makes many “substructure microflares” in core fields, and
- Is controlled by some episodic process.

Magnetic flux cancellation driven at the neutral line by episodic convective flows in and beneath the photosphere is a process that plausibly meets all of these requirements.

The MSFC scientists therefore infer from their observations that:
- The strong coronal heating rooted in active regions is done by core-field microflaring paced by magnetic flux cancellation; and
- The microflaring activity directly produces the enhanced coronal heating in the core fields and also generates MHD waves that propagate up into the enhanced extended loops to provide the strong coronal heating in these.

Falconer, D.A.; Moore, R.L.; Porter, J.G.; Gary, G.A.; Shimizu, T.: “Neutral-Line Magnetic Shear and Enhanced Coronal Heating in Solar Active Regions.” *Astrophysical Journal*, 1996, in press.

Moore, R.; Porter, J.; Roumeliotis, G.; Tsuneta, S.; Shimizu, T.; Sturrock, P.; Acton, L.: “Observations of Enhanced Coronal Heating in Sheared Magnetic Fields.” Proceedings of the Kofu Symposium “New Look at the Sun,” ed. S. Enome and T. Hirayama, Nobeyama Radio Observatory Report no. 360, p. 89, 1994.

Porter, J.; Moore, R.; Roumeliotis, G.; Shimizu, T.; Tsuneta, S.; Sturrock, P.; Acton, L.: “Microflaring at the Feet of Large Active Region Loops.” Ibid., p. 65, 1994.

Sponsor: Office of Space Science

University/Industry Involvement: University of Tokyo; Stanford University; Montana State University

Biographical Sketch: Dr. Ronald L. Moore is an internationally recognized solar scientist. He received his Ph.D. from Stanford University in 1972, was a Research Fellow with the Caltech Solar Astronomy group (1972 through 1980), and joined the MSFC Solar Physics branch in 1981. There, he developed and continues to lead a research program on observed solar magnetic fields and their effects in the solar atmosphere. Moore has published over 100 papers on his solar research in refereed journals, conference proceedings, books, and encyclopedias.